Draft Ground Water
Report 9/3/92

CHAPTER 1

INTRODUCTION

The Cedar Hills Regional Landfill is a 920-acre site that has received mixed municipal solid waste since 1964. The site is located in south-central King County, Washington, approximately 20 miles southeast of Seattle.

Seasonal ground water quality has been monitored at the Cedar Hills Regional Landfill since 1983. A large quantity of data has been developed for the site as a result of the monitoring program and in accordance with the Washington State Minimum Functional Standards for Solid Waste Facilities. This report is the 1992 Annual Ground Water Data Evaluation Report which serves to review the data collected between July, 1989 and March, 1992 and evaluate the significance of any trends that may be indicated these data.

In order to effectively analyze the water quality data, it is important to have a clear understanding of the regional and site geology and hydrogeology, and to understand ground water occurrence beneath the Cedar Hills site. Chapter 2 provides a brief description of the site geology and hydrogeology; however, it is highly recommended that the reader review the previous ground water evaluation report entitled <u>Cedar Hills Regional Landfill - Evaluation of Ground Water Quality Data, 1986 through Mid-1990, Sweet-Edwards/EMCON, April, 1991</u> for a more detailed description of the hydrogeologic conditions below the site.

CHAPTER 2

GEOLOGY/HYDROGEOLOGY

This chapter provides a brief discussion of the geology and hydrogeology at Cedar Hills. The reader is again encouraged to review the 1991 Ground Water Evaluation Report (Sweet-Edwards/EMCON, April, 1991) for a more detailed description of the hydrogeologic conditions at Cedar Hills.

A number of hydrogeologic investigations have been conducted at and around Cedar Hills. The stratigraphic unit numbering system which has been adopted for Cedar Hills is the same system developed for the Queen City Farms CERCLA site located immediately south of Cedar Hills (Remedial Investigation Report - Queen City Farms - King County, Washington, Landau Associates, April 20, 1990). This system uses a letter designation (unit A through unit J) that identifies significant stratigraphic units (from youngest to oldest) beneath the site. Table 2-1 contains a summary description of the Cedar Hills site stratigraphy. Figure 2-1 is a north-south cross section showing the occurrence and variations in thickness of units encountered beneath Cedar Hills.

At least two ground water systems have been identified at Cedar Hills including a local flow system that encompasses the Vashon age deposits and a regional flow system that encompasses the pre-Vashon deposits. The local flow system contains at least three shallow aquifers of variable extent, and the regional flow system contains at least two deeper aquifers, present beneath the entire site. Figure 2-2 is a conceptual hydrogeologic cross section that illustrates the relationships between aquifer occurrence and geologic units present at the site.

Regional Aquifers

Two regionally extensive aquifers have been identified in the pre-Vashon stratigraphic units.

Aquifer 2 appears to be restricted to stratigraphic unit F; it is approximately 25 feet in thickness, and exhibits unconfined aquifer conditions. The aquifer appears to be recharged principally south of the site although some localized recharge may occur at Cedar Hills. The ground water flow gradient for Aquifer 2 is towards the north, northwest, and northeast of Cedar Hills. Water quality in Aquifer 2 has been monitored in two monitoring wells (MW-56 and MW-57) on the southern property boundary.

Aquifer 3 is contained within stratigraphic units H, I, and J, and is separated from Aquifer 2 by a silt aquitard (unit G). Unit I is also a silt aquitard that separates sands in unit H from sands in unit J. It is not known whether unit J is hydraulically separate from unit H since all the data concerning unit J are based on monitoring well MW-54. Until new data indicate unit J is separate from unit H, it is recommended that sand unit J be considered a lower part of Aquifer 3.

KCSWD currently monitors Aquifer 3 in nine wells beneath CHL (MW-21, MW-22, MW-24, MW-43, MW-44, MW-53, MW-58, MW-59, and PW-1) and in one off-site well (OS-1). KCSWD currently monitors Aquifer 3 (lower) in one on-site well (MW-54) and in three off-site wells (OS-2, OS-3, and OS-4).

The piezometric surface contour map (Figure *) constructed from monitoring well data indicates a north and northeasterly flow direction in Aquifer 3.

Vertical hydraulic gradients between Aquifer 2 and Aquifer 3 determined during the QCF/CHL remedial investigation indicate a downward gradient from Aquifer 2 to Aquifer 3. The vertical gradient appears to be greatest south of CHL where recharge appears to be occurring beneath the QCF site. The vertical flow gradient beneath CHL is not accurately known, but, according to boring log data appears to be less than the gradient beneath QCF.

Local Aquifers

At least three local aquifers are identified in the Vashon aged units at Cedar Hills as follows:

1.	Recessional outwash aquifer	(Aquifer 1)
2.	Ground water perched in till	(No aquifer designation)
3.	Stratified Drift	(No aquifer designation)

Recessional Outwash Aquifer -- Aquifer 1 is a perched aquifer restricted to the basal portion of the recessional outwash (unit C) where it overlies the low-permeability till. Ground water flow is probably controlled by the dip and strike of the till perching horizon. The aquifer has been located in isolated borings drilled on the western property boundary, but is not monitored present at Cedar Hills. The aquifer is more extensive south of Cedar Hills and is monitored at the Queen City Farms site.

Glacial Till -- Ground water within the glacial till (unit D) occurs in several monitoring wells within lenses of sand and/or gravel. Ground water ~~does~~ is not ~~appear to be~~ continuous and no ground water flow directions ~~has~~ have been determined. No aquifer letter designation has been applied to ground water contained in the till.

Stratified Drift Aquifer -- The Stratified Drift Aquifer is contained in lower sections of the stratified drift unit (E_U). Saturated thickness varies from zero to 30 feet. Water-bearing horizons within the aquifer frequently exhibit confined aquifer conditions. Recharge to the aquifer occurs locally on the site by direct infiltration and vertical leakage from water in the overlying till when present. Ground water flow appears to be controlled by local topography; piezometric contours typically follow ground surface contours. No perching unit underlies the Stratified Drift Aquifer which probably discharges through leakage of ground water from the base of the aquifer and possibly to local water courses. No aquifer letter designation has been applied to the Stratified Drift Aquifer.

CHAPTER 3

DATA EVALUATION

In this chapter, the analytical data for selected parameters are examined, and seasonal or other temporal trends in water quality are evaluated. The water quality has been assessed by water bearing zone in addition to by individual wells completed within each zone. The indicator parameters examined include pH, specific conductance, COD, chloride, total inorganic nitrogen, COD, chloride, sulfate, dissolved iron, and dissolved manganese. Additional parameters such as other dissolved metals, fluoride, and organics are examined as appropriate. In general, the period of record for the evaluation of the wells is July, 1989 to March, 1992. It should be noted, however, that the period of record and/or the quantity of data available for certain wells is somewhat limited, which precludes comprehensive analyses of ground water trends in these wells.

3.0 DATA EVALUATION METHODS

The following statistical and graphical methods have been used to evaluate the data: box and whisker plots, time trends, and descriptive statistics. Box and whisker plots (made with Systat 5.03) provide a data analysis tool that is useful for studying location and symmetry of distributions, and outliers. These plots are included in Appendices * to *, and are grouped according to water bearing zone. Each box plot divides the data set into four areas of equal frequency. The box encloses the middle 50 percent of the data with the median indicated by a horizontal line. The lower whiskers extend from the second quartile down to the smallest data point within 1.5 times the interquartile range. The upper whisker extends up from the third quartile to the largest data point within 1.5 times the interquartile range. Those data points lying between 1.5 times and three times the interquartile range are designated with an "*". Points lying beyond three times the interquartile range are designated with an "o". Box plot construction is more fully described by Wisconsin Department of Natural Resources Bureau of Solid and Hazardous Waste Management (Fisher and Potter, 1989), Washington State Draft Groundwater Monitoring Guidance for Solid Waste Facilities (WDOE, 1989), and Rekow and Chapra (1983).

In addition to box plots, time plots are also included in Appendices ___ through ___, and are grouped according to water bearing zone. Table ___ summarizes the parameters that are plotted for each well. Summary statistics are compiled in Table ____, and include maximum, minimum, mean, median and standard deviation values. Although both means and medians are reported in the summary table, medians are used more frequently in the text because they tend to be a more reliable measure of central tendency in the case of non-normal distributions, particularly when there are outliers, as is the case here.

One important aspect of data treatment is the manner in which undetectable values are handled. In this report, all non-detections (ND) are displayed on graphs as one-half the limit of detection. These values can readily be seen on the time trends because they fall below the line demarcating the detection limit. For box plots and statistical calculations, one-half the detection limit is also used in place of non-detections.

Finally, ground water data are compared to water quality standards in the Minimum Functional Standards for Solid Waste Handling (WAC 173-304), the State Ground Water Protection Standards (WAC 173-200), and the Federal Primary and

Secondary Drinking Water Standards. It should be noted that not all parameters have standards. For instance, there are no standards for dissolved metals. In addition, some standards have changed during or after the period of investigation. What has been attempted here is to use only those standards that were applicable at the time of sampling.

3.1 DATA QUALITY

Data quality has been described in YE's Laboratory Data Validation report for the Duvall, Enumclaw, Vashon, Hobart, and Cedar Hills landfills (Appendix *IV). Some points that deserve reiteration here include: laboratory and method changes, blanks, detection limits, and duplicates. During the period of investigation, two different laboratories performed chemical analyses: Laucks, Inc., prior to March 1990, and subsequently, Amtest, Inc. Concurrent with this switch, some analytical methods were also changed. These changes may have affected data quality.

Blank contamination has important ramifications for data quality. For this reason, mention has been made in the discussion, whenever possible, of concentrations present in blanks. However, for some compounds, such as methylene chloride and acetone, the occurrences of blank contamination are too numerous to mention each separate event. Therefore, only certain instances of blank contamination are reported for these compounds. Other compounds, such as, sulfate, zinc and iron have also been detected in blanks. These detections will be noted for the individual wells in which they occur.

Some general implications regarding data quality follow from the occurrence of blank contamination. Since the laboratory is a likely source of blank contamination, especially in the case of solvents, some qualification of the data is necessary. Therefore, based on blank contamination events, along with measures of precision and accuracy, the following list of qualified constituents (Table *) has been compiled. The reader is encouraged to use caution when interpreting data regarding these constituents. To delve further into this subject, the reader is referred to the Data Validation Report (Appendix *IV) for a more detailed review of blanks, precision and accuracy.

There are many instances, particularly in the case of organic parameters where the limit of detection is above state or federal water criteria levels. Thus, there may be concentrations above the levels of the standard. However, because these concentrations are unmeasurable they cannot be reported. Another issue involving these limits arises when the limits of detection change. Especially noticeable for metal parameters, these changes may be due to dilution, or due to technical or contractual specifications.

Regarding duplicates, when more than one sample was taken on the same day, the results were averaged for purposes of graphing on time plots. All values, however, were used in creating box plots and in computing statistics. When averaging has obscured maxiumum values on the time plots, this fact is noted in the text.

3.2 BACKGROUND: CHEMICAL INDICATORS OF POTENTIAL LEACHATE OCCURRENCE

pH indicates hydrogen ion activity. Ground water is typically slightly acidic. Leachate may be acidic, neutral, or slightly basic as a function of refuse age.

Leachate contains high levels of cations, including calcium for example, and cation exchange with soils tends to release hydrogen ions from soil to lower ground water pH. Any long-term trend seen in ground water may be considered a potential indicator of leachate influence.

Specific conductance is a measure of the ability of water to carry an electrical current. This property is related to concentration, charge, ion mobility, and water temperature. Solutions of acids, bases, and salts have higher conductivity than solutions of organic compounds. Ground waters in the Northwest, depending upon location and depth, generally have conductivities in the range of 100 to 500 uS/cm. Leachate has high conductivity, typically ranging from 500 to 50,000 μS/cm. Sodium and chloride are the principal conductive constituents in leachate. As a result, specific conductance can be a good leachate indicator but provides information redundant to that of chloride and sulfate.

Chloride is a conservative anion, that is, transport of chloride in ground water is generally not retarded by processes of adsorption, ion exchange, or biological uptake. It typically occurs at levels less than 20 mg/L in ground water depending upon local geologic conditions and at concentrations of 500 to 2,000 mg/L in leachate. Because of its high solubility and low tendency for retardation, chloride usually marks the leading edge of a leachate plume and is typically the first indication of an impact from leachate.

Sulfate is not as mobile as chloride due to its potential adsorption into the soil. Sulfate levels are routinely less than 20 mg/L in ground water and 100 to 2,000 mg/L in leachate. However, the levels in leachate may be high enough to saturate the available adsorption sites in soil, and as a result, sulfate is also an early warning of leachate migration. The separation between the onset of the chloride increase and the sulfate increase (sometimes on the order of one year) provides general information about the extent to which the soil may retard migration of other compounds.

COD, chemical oxygen demand, is a measure of the oxygen required to oxidize both organic matter and certain inorganic compounds. The COD in ground water is typically less than 100 mg/L and in leachate ranges between 500 and 50,000 mg/L. A number of volatile organic compounds and other short-chain organic compounds are mobile and can contribute to COD as a result of leachate migration.

Inorganic nitrogen is measured as the sum of ammonia, nitrate, and nitrite. In leachate, it exists primarily as ammonia due to the reducing conditions typically present within a landfill, and in ground water, it exists primarily as nitrate, the oxidized form. Nitrate is moderately mobile through soils and is, therefore, an early indicator of leachate impacts to ground water. As ammonia leaches from the landfill, it is oxidized to nitrate and is readily mobilized. Typical concentrations of inorganic nitrogen are 100 to 1,000 mg/L in leachate and less than 10 mg/L in ground water. However, because the carbon to nitrogen ratio of leachate is very high, carbon typically limits bacterial growth rates. A leachate plume stimulates the growth of soil bacteria by providing organic carbon as food. The enhanced bacterial growth in turn consumes available nitrogen. Therefore, a typical response indicating leachate migration as detected in monitoring wells may be a decline of nitrate as it is consumed by bacteria growth (Smayda and Owes, 1990). This decline generally lags behind the increase in sulfate levels. Thus, trends of increase or decrease in inorganic nitrogen may indicate leachate migration.

Manganese and iron are present in leachate and may also be mobilized from the soil if oxygen levels decline to near zero, a phenomenon which could happen as a result of oxygen demand within the leachate plume. Iron and manganese behave similarly, but iron requires a slightly greater decline in oxygen levels to be mobilized; therefore, it typically appears in a monitoring well after manganese. Natural levels of iron and manganese are extremely variable, and exceedances of secondary drinking water criteria routinely occur in King County (Richardson et al., 1968). Iron and manganese are best used as leachate indicators by assessing their change in concentration over time, rather than by presence and absence, or by comparison to standards.

Available data (Smayda and Owes, 1990) suggest that a relatively fixed sequence of leachate indicator species appear in impacted wells. Conservative salts such as chloride move rapidly from a fill at the leading edge of a leachate plume, as also indicated by elevated specific conductance. Sulfate closely follows, with a lag which is likely a function of the sulfate adsorption capacity of the soil. Manganese, then iron follow. The source of these metals may be leachate or, if redox is depressed, the soil itself. Organic compounds tend to follow iron.

3.3 DATA ANALYSIS

<u>Ground Water Perched in Glacial Till, Unit D</u>

There are five monitoring wells completed within the Glacial Till, unit D

(MW-32, MW-39, MW-42S, MW-48, and MW-50, see Figure ___). Data for MW-32, MW-48 and MW-50 are limited since these wells were removed from the quarterly monitoring schedule in 1991 due to insufficient quantities of water. The time to collect a sample from these wells exceeded two to three weeks. In addition, MW-25 is another Glacial Till well which was included in the previous ground water evaluation report, but is not included herein since it is not on the existing quarterly monitoring schedule. MW-25 was installed and only monitored as part of the South Cedar Hill Remedial Investigation completed in 1990.

*(refer to hydrogeologic discussion of till unit - ie. no up or downgradient wells)

The box plots and time plots for selected parameters for the Glacial Till wells are presented in Appendix ___. A summary of the exceedances of the ground water criteria is included in Table ___. A discussion of the box plots, time plots and exceedances are presented below, first for the Glacial Till unit in general and then by individual well.

<u>Indicator and Non-metal Parameters</u>

pH

The range of pH in the five wells in the Glacial Till unit varies widely from 5.4 to 8. There are points outside the state and federal secondary standard range in MW-39 and MW-42S, and these two wells are largely acidic. The lowest reading, 5.4, appears as a low outlier in MW-39. The other three wells tend to have alkaline values, the highest of which occurs in MW-50. MW-50 also has the broadest range of values, as shown on the box plots, Figure *, compared to the relatively narrow ranges of the other wells. Time plots, Figures * through *, indicate that MW-48 has the fewest data points and also the least amount of fluctuation. MW-39 and MW-50 have the largest fluctuations between consecutive readings on the order of more than one pH unit. No temporal trends are evident in pH levels.

Specific Conductance

The specific conductance readings span a broad range, from 16 to 1200 µS/cm. The lowest values are found in MW-32 which has an outlier of 16 µS/cm. The highest values are found in MW-42S which has an outlier of 1200 µS/cm. Except for outliers, ranges are narrow in MW-32, MW-48 and especially MW-50, as depicted in the box plots, Figure *. Ranges are broader in MW-39 and MW-42S. As illustrated by time trend plots, Figures * through *, MW-32 and MW-50 have stable conductance levels. MW-42S has moderate fluctuations between readings and MW-39 has larger fluctuations of up to about 500 µS/cm between consecutive readings. MW-48 has fewer data points, but appears to exhibit the only steady increase in conductance in this unit.

COD

In the Glacial Till unit, COD concentrations range from below detection to 82 mg/L, as indicated on the box plots, Figure *. The lowest readings are found in MW-50 (no detections) and MW-32 (two detections, 11 and 32 mg/L). The highest values and broadest range are found in MW-48. However, MW-39 has the highest median 29 mg/L). Time plots, Figures * through *, indicate that MW-42S and MW-48 have large fluctuations between consecutive readings (about 60 mg/L) and MW-39 has relatively moderate fluctuations of up to 30 mg/L between readings. No long-term trends are evident.

Chloride

Chloride concentrations range from below detection to 150 mg/L. The box plots, Figure *, indicate that MW-32 and MW-50 have the lowest values except for one anomalous outlier in MW-50 at 150 mg/L. MW-42S and MW-48 have the highest medians at 18 and 19 mg/L, respectively. The box plots indicate little variability in MW-32 and MW-50, with broader ranges in the other wells. The time trends, Figures * through *, show larger fluctuations in the other wells except for the outlier in MW-50. All values are below the secondary chloride standard of 250 mg/L, and no trends are seen.

Fluoride

The box plots, Figure *, depict some range overlap among several of the wells. Typical fluoride values in the unit are below 0.1 mg/L. MW-50, however, stands out as having higher fluoride concentrations (up to 0.3 mg/L) in general, than the other wells. Time trends of MW-32 and MW-50, Figures * through *, show little variability. The graphs of MW-39, MW-42S, and MW-48 show slight fluctuations. No temporal patterns are apparent. Furthermore, none of the values surpasses state or federal secondary drinking water standards of 2 mg/L.

Sulfate

Sulfate levels in the Glacial Till unit are variable and range from below detection to 130 mg/L. Apparent from the box plots, Figure *, is the occurrence of low values and narrow ranges in MW-32 and MW-42S, in contrast to the broader higher values found in the other wells. The concentrations in MW-32 and MW-42S are stable, as displayed by the time trend plots, Figure * through *. Sulfate levels in MW-50 have declined dramatically during the previous reporting period and may have stabilized at around 35 mg/L during the current period. Using previous data, it is evident that sulfate levels at MW-48 declined up through 1989 then began to increase. There are large fluctuations of over 100 mg/L between readings in MW-39, and this well appears to experience seasonal trends with low values in late summer and high values in winter. No sulfate concentrations in this unit exceed the state and federal secondary standard of 250 mg/L.

Total Inorganic Nitrogen

There are two distinct levels of total inorganic nitrogen displayed in this unit: the first, present in MW-32, MW-42S, and MW-50 is below 1 mg/L; the second, found in MW-39 and MW-48 is above 1 mg/L. The total range is from 0.03 to 4.1 mg/L, and the top value is an outlier in MW-39 (see box plots, Figure *). The wells with the lower values are characterized by narrow, stable concentrations, whereas the wells with the higher values have broad ranges and fluctuating concentrations. There are no temporal trends in total inorganic nitrogen levels with the exception of a possible decline in MW-39. No values exceed the primary state and federal standard of 10 mg/L for nitrogen from nitrate.

<u>Metal Parameters</u>

Dissolved Arsenic

The range of dissolved arsenic is from below detection to about 0.015 mg/L. However, it is clear from the box plots, Figure *, that most values lie below 0.006 mg/L with many falling below the limit of detection. It is only in MW-39 that the values are consistently higher. MW-39 also has the broadest range and the largest fluctuations (up to 0.014 mg/L between readings). The other wells tend to have stable dissolved arsenic concentrations except for rare spikes such as the outliers in MW-48 (0.008 mg/L) and MW-50 (0.01 mg/L). No temporal trends are seen. None of the values exceeds the federal primary standard of 0.05 mg/L. However, all detectable readings of dissolved arsenic exceed the state standard of 0.05 μg/L because the standard itself lies below the detection limit.

Dissolved Barium

Similar to the pattern of dissolved arsenic the levels of dissolved barium in the unit are largely below 0.05 mg/L in all wells except for MW-39. The total range is from below detection to 0.12 mg/L with a high outlier of 0.19 mg/L occurring in MW-39 (refer to box plots, Figure *). Dissolved barium is not detected in MW-32 or MW-50. In MW-42S there are three detections (maximum 0.12 mg/L) and in MW-48 only two (maximum 0.06 mg/L). Concentrations in MW-39 fluctuate around 0.1 mg/L with a high outlier at 0.19 mg/L. As can be seen in the time plots, Figures * through *, no trends are apparent and no exceedances of state or federal standards (1.0 mg/L) for total barium occur.

Dissolved Copper

Most readings of dissolved copper are near or below the limit of detection in this unit. There is one high outlier in MW-32 at 0.037 mg/L (see box plots, Figure *). All other detections are below 0.01 mg/L. No trends are seen and no exceedances occur (see time plots, Figure * through *).

Dissolved Iron

Dissolved iron ranges from below detection to 26 mg/L. However, only MW-39 has values above 2 mg/L, as illustrated by the box plots, Figure *. MW-32 and MW-50 have relatively low values ranging from below detection to 0.15 mg/L. MW-42S has values up to 0.57 mg/L, five out of 19 of which exceed the state and federal secondary standard of 0.3 mg/L for total iron. MW-48 ranges from 0.27 to 2 mg/L, and three out of five results exceed the secondary standard. MW-39 has a much broader range from 12.8 to 26 mg/L, and all 12 sample results exceed the secondary standard. No seasonal or other temporal trends are evident in the raw data (time trends are obscured by the scale).*

Dissolved Manganese

Patterns in dissolved manganese concentrations are similar to those of iron, as shown by the box plots, Figure *. The overall range is from below detection to 10 mg/L, with values above 1 mg/L occurring in MW-39. MW-32 has two detections (maximum 0.02 mg/L) and MW-50 has a maximum level of 0.04 mg/L. None of these values exceeds the 0.05 mg/L state and federal secondary standard for total manganese. However, all values at wells MW-39, MW-42S, and MW-48 exceed the secondary standard for total manganese. Of these three wells, MW-39 shows the most variation, including fluctuations up to 4 mg/L between readings. MW-42S shows a declining trend followed by an abrupt jump up by almost 1 mg/L (not clear on time plot, Figure *, due to scale).

Dissolved Zinc

The box plots, Figure *, indicate less variation in dissolved zinc levels than occurs with some other parameters. In general, zinc levels are below 0.03 mg/L though there are several outliers ranging up to a maximum of 0.15 mg/L. Time plots, Figure * through *, show levels in MW-32, MW-39, and MW-50 near or below the limit of detection. Of the few samples taken in MW-48, three show detectable levels of dissolved zinc (maximum 0.05 mg/L). The most unique well is MW-42S which experiences large fluctuations of more than 0.1 mg/L between consecutive readings. Using previous data, it is evident that low stable dissolved zinc levels in this well have been replaced by these larger fluctuating values. In terms of absolute magnitude, however, the peak concentration at MW-42S and the entire unit, 0.15 mg/L, is far below the state and federal secondary standard of 5 mg/L.

<u>Organic Parameters</u>

Two organics, 1,2-DCA and 1,2-DCE appear in MW-42S, as depicted by box plots shown in Figures * and *. No other organics are detectable in this unit. The concentration of 1,2-DCA ranges from below detection to a high spike of 11 μg/L, with a mean value of about 4 μg/L. Except for the highest concentration, levels of 1,2-DCA are fairly stable and no trends are apparent (see time plot, Figure *). Of 20 samples, three have readings above the federal standard of 5 μg/L, and 18 have readings above the state standard of 0.5 μg/L.

For 1,2-DCE (<u>cis</u> and <u>trans</u>), the range is from below detection to 4 μg/L. Of 20 samples, nine readings are above the limit of detection. Although fluctuations of greater than 3 μg/L occur between readings, as shown by the time plot, Figure *, the typical value of detectable concentrations is about 3 μg/L. During the period under investigation, there are no applicable state* of federal standards.

INDIVIDUAL WELLS

MW-32 -- MW-32 is located within the property boundary near the southwest corner of the site and is screened between 49 ft and 59 ft below ground surface (bgs).

Indicator and Non-metal Parameters

MW-32 has slightly basic ground water with a pH range of 6.61 to 7.64 and a median of 7.36. The specific conductance ranges from 16 to 180 $\mu S/cm$ with a mean of 152.5 $\mu S/cm$ and is noticeably lower in MW-32 than in other wells within this unit. Other indicators are also low: COD (5 - 32 mg/L), chloride (0.5 - 4.1 mg/L), fluoride (less than 0.2 mg/L), sulfate (10-15 mg/L), and total inorganic nitrogen (0.42 - 0.82 mg/L).

Metal Parameters

As with the non-metal indicators, the metals in MW-32 are not present in high concentration. Dissolved iron ranges from non-detection (ND) to 0.14 mg/L with a median of 0.025 mg/L. Dissolved manganese ranges from ND to 0.02 mg/L with a median of 0.005 mg/L. All other dissolved metals range from below detection to the following maximum values: arsenic (0.003 mg/L), barium (less than 0.05 mg/L), copper (0.037 mg/L), and zinc (0.02 mg/L).

Organic Parameters

No volatile organic compounds are detectable in this well except acetone and methylene chloride. Acetone ck blanks* is found in three samples at levels of 18, 53, and 100 $\mu g/L$. Methylene chloride is found in six samples, five of which are accompanied by contaminated method blanks. One of these methylene chloride detections, 9.5 $\mu g/L$, exceeds the relevant state and federal criterion of 5 $\mu g/L$.

Trends

MW-32 is characterized by low, stable parameter concentrations which suggest no leachate impact at this site.

MW-39 -- MW-39 is located approximately 600 feet within the southern site property boundary and is screened between 8 ft and 18 ft bgs.

Indicator and Non-metal Parameters

MW-39 is the most acidic well in the Glacial Till unit, with a pH range of 5.4 to 6.83. The median and mean lie close to each other at 6.305 and 6.323, respectively, indicating a fairly even distribution of values with the exception of the low point at 5.4. Because these are field data, there is no method blank with which to compare the low value. Specific conductance, COD, Cl, and F levels are all within the middle of the range for the entire unit, as follows: specific conductance (475 - 764 μS/cm, median 593 μS/cm), COD (5 - 45 mg/L, median 29 mg/L), Cl (0.5 - 18 mg/L, median 9.35 mg/L), and F (0.02 - 0.32 mg/L, median 0.06 mg/L). In contrast, the total inorganic nitrogen and sulfate levels tend to be higher in this well, with a nitrogen range of 0.87 - 4.1 mg/L (median 1.73 mg/L) and a sulfate range of 19 - 130 mg/L (median 57.5 mg/L. The high nitrogen value is largely due to elevated ammonia. There may also be a decreasing trend in nitrogen.

Metal Parameters

Along with dissolved iron and manganese, arsenic and barium are notably higher in this well than in other wells in the Glacial Till unit. Dissolved iron ranges from 12.8 to 26 mg/L with a median of 21.5 mg/L. Dissolved manganese ranges from 4.6 to 10 mg/L with a median of 7.2 mg/L. All iron and manganese concentrations are above secondary state and federal criteria levels for ground water. The range for dissolved arsenic is ND - 0.015 mg/L (median of about 0.012 mg/L). One of these is a non-detection, with the remaining eleven detections falling above the state criterion of 0.05 µg/L, but below the federal criterion on 0.05 mg/L. For dissolved barium the values are evenly spread from 0.07 to 0.12 mg/L with one outlier at 0.19 mg/L. Dissolved copper and zinc levels are at or close to ND with maximums, respectively, of 0.006 mg/L and 0.04 mg/L (not indicated on graph because two samples from the same day were averaged).

Organic Parameters

No organics were detected in MW-39 except methylene chloride. In all cases, methylene chloride was also present in the method blank.

Trends

Apparently, no trends are occurring in MW-39 except perhaps for a decline in inorganic nitrogen. The relative concentrations of several parameters appear to be more variable than in other wells. For instance, pH, specific conductance, Cl, F, Ba, and Zn all exhibit moderate fluctuations, while COD, inorganic nitrogen, sulfate, As, Fe, and Mn exhibit more marked variability compared to other wells in this unit. It is unclear whether or not these fluctuations stem from leachate impacts.

MW-42S -- MW-42S is located in close proximity to MW-39 near the southern property boundary and is screened between 25 ft and 35 ft bgs.

Indicator and Non-metal Parameters

Like MW-39, MW-42S is typically acidic with only one pH value above 7. The pH range, 6.27 to 7.04, is evenly distributed around a mean of 6.569. Five out of 17 pH values are outside the secondary standard range. Although substantially higher than in other Glacial Till wells, specific conductance is also fairly evenly distributed around a median of 858 µS/cm (range 770 - 1200 µS/cm), except for one high outlier at 1200 µS/cm. COD concentrations in MW-42S are moderate in magnitude, but highly variable within a range of 5 to 69 mg/L (median 11 mg/L). Chloride levels are similar to those in MW-48 and range from 0.5 to 24 mg/L. Fluoride (0.01 - 0.4 mg/L, median 0.02 mg/L), sulfate (0.5 - 11 mg/L, median 6 mg/L), and total inorganic nitrogen (0.03 - 0.43 mg/L, median 0.04 mg/L) all have average concentrations below those found in other Glacial Till wells.

Metal Parameters

Dissolved iron ranges from ND to 0.57 mg/L with the top two values surpassing the secondary federal and state criterion of 0.3 mg/L for total iron. It should be noted, however, that the method blank used in conjunction with the sample reading 0.57 mg/L, shows an iron concentration of 0.04 mg/L. All 19 of the dissolved manganese readings in this well (range 0.3 to 1.1 mg/L) exceed the secondary criterion of 0.05 mg/L for total manganese. Seven of the samples have dissolved arsenic concentrations below detection. The remaining twelve samples have arsenic concentrations ranging from 0.001 to 0.003 mg/L, all of which are above the state criterion of 0.05 μg/L, but below the federal standard 0.05 mg/L for total arsenic. Dissolved barium is not detectable except in three samples, at 0.02, 0.08, and 0.12 mg/L. Likewise, dissolved copper is not detected except for two points which lie close to the limit of detection. Only three samples have dissolved zinc levels significantly above the limit of detection (0.099, 0.13, and 0.15 mg/L). However, none of these exceeds regulatory standards.

Organic Parameters

MW-42S is the only well within the Glacial Till unit to show detectable levels of other volatile organic compounds besides acetone and methylene chloride. Levels of 1,2-dichloroethane range from ND to 11 μg/L, with most values centering around 4 μg/L. The majority of these values exceed the state criterion of 0.5 μg/L, but are below the federal standard of 5 μg/L. No 1,2-DCA was detected in the method blanks. 1,2-DCE was also detected in the range ND - 4 μg/L. Acetone is present in three samples in the concentrations of 16, 20, and 100 μg/L, but is evidently not found in the corresponding method blanks. Methylene chloride ranges from ND to 19 μg/L and is present in all accompanying blanks except one.

Trends

Overall, the concentrations in this well tend to be variable with frequent outliers. There is a possible declining trend in chloride (refer to previously reported data), but otherwise there are no apparent long-term seasonal or other temporal trends. The presence of 1,2-DCA and 1,2-DCE, in addition to the high specific conductance in this well, suggests impacts from leachate.

MW-48 -- MW-48 is located within the site property boundary in the southeast corner approximately 500 feet from the eastern boundary line and is screened between 37 ft and 47 ft bgs.

Indicator and Non-metal Parameters

This well was abandoned partway through the sampling period, in April, 1992. Because there are, in general, only five sampling points, the interpretation of results is limited. The pH at MW-48 is similar to that of MW-32, with a slightly basic range of 7 to 7.36, and a median of 7.26. Specific conductance (371 - 690 uS/cm) is similar to but slightly lower than levels at MW-39 within the same unit. COD in MW-48 is similar in magnitude to the rest of the wells, but is more variable (ND - 82 mg/L). Chloride tends to be slightly higher at this well with values ranging from 12 to 23 mg/L. Fluoride levels remain at or close to the detection limit (maximum 0.4 mg/L). Total inorganic nitrogen ranges from 0.63 to 2.1 mg/L with the higher values due primarily to elevated ammonia. Sulfate has a skewed distribution and ranges from 2 to 77 mg/L with a median of 10 mg/L.

Metal Parameters

The level of dissolved iron in MW-48 ranges from 0.27 to 2 mg/L with 3 of 5 values exceeding the 0.3 mg/L criterion level for total iron. Dissolved manganese concentrations (0.5 - 0.81 mg/L) all exceed the criterion of 0.05 mg/L for total manganese. Dissolved arsenic, barium, and copper hover at or close to the limits of detection. The maximum detected arsenic concentration (0.008 mg/L) lies between the state and federal regulatory levels for total arsenic. Values for dissolved zinc range below 0.012 mg/L.

Organic Parameters

Only one sample for acetone (150 μg/L) and three samples for methylene chloride (1.1, 2.3, and 6.8 μg/L) have detectable concentrations. For the latter, one laboratory blank was also contaminated.

Trends

The most obvious trend occurring in this well taking previously reported data into account is a decline followed by an increase in sulfate concentration. Leachate impacts may be reflected in the highly variable COD values, or the relatively high chloride, fluoride, and inorganic nitrogen concentrations. However, because data are limited, interpretation is tenuous.

MW-50 -- MW-50 is located on-site on the eastern side of the property and is screened between 27.5 ft and 37.5 ft bgs.

Indicator and Non-metal Parameters

Within the unit, MW-50 displays the highest variability in pH as well as the highest range of values (6.67 - 8). In contrast, specific conductance is stable in the range of 290 - 330 μS/cm. COD is not detectable in this well, and chloride levels remain near the limit of detection except for one anomalous point at 150 mg/L. Fluoride (ND - 0.2 mg/L) is higher than in other wells in the unit. Sulfate levels are moderately high (36 - 77 mg/L, median 42 mg/L), whereas total inorganic nitrogen concentrations (0.07 - 0.32 mg/L) are slightly low compared to other wells.

Metal Parameters

None of the dissolved metal concentrations exceed criterion levels for total metals except for arsenic, which ranges from ND to 0.01 mg/L (median 0.004 mg/L). No dissolved barium is detected, and dissolved copper levels are moderate (ND - 0.009 mg/L). Three of nine samples have detectable levels of dissolved iron: 0.06, 0.08, and 0.15 mg/L. Dissolved manganese varies from ND to 0.04 mg/L. Dissolved zinc ranges from ND to a maximum of 0.02 mg/L.

Organic Parameters

No volatile organics are detected in MW-50 except for acetone (16 μg/L) and methylene chloride (maximum 8 μg/L). All detections of both compounds are accompanied by contaminated blanks.

Trends

When viewed in conjunction with previously reported data, the results show a continuing, but slight, decline in sulfate levels. For the remaining parameters, however, no trends are evident. MW-50 has high pH, fluoride, and sulfate, and moderate arsenic and copper compared to the other wells in the unit. However, it does not seem likely that there is active leachate infiltration occurring here.

Ground Water Perched in Stratified Drift, Subunit Eu

Nine wells are currently being monitored within the Stratified Drift, Subunit E_u including MW-27A, MW-28, MW-29, MW-30A, MW-42D, MW-55, MW-47, MW-62 and EB-6 (Figure *). Monitoring wells MW-47, MW-62 and EB-6 are located near MW-30A and have only been recently added to the quarterly monitoring schedule. Since there are insufficient data to perform any type of statistical evaluation on these three wells, the data will only be presented in tabular form. It should also be noted that MW-28 has fewer data values and MW-30A has more data values than the other wells. These discrepancies in number of readings may have a slight effect on interpretation.

The box plots and time trends for selected parameters are presented in Appendix _. A summary of the exceedances are shown in Table ___. A summary of the box plots, time trends and exceedances for the entire unit are presented below followed by summaries for each individual well in the unit.

Samples from MW-28, MW-30/MW-30A and MW-42D indicate that water quality in the Stratified Drift unit has been impacted by site activities at CHL. The type and degree of impact, however, are different for each well, which is as expected considering their relative locations.

Data from monitoring wells MW-27A, MW-29, and MW-55 show no significant water quality impact in the Stratified Drift unit.

Indicator and Non-metal Parameters

pH

Overall, the pH ranges from 5.93 to almost 8 in the six wells in the Stratified Drift unit. Half of these wells have pH ranges spanning less than one pH unit, and all have median values lying within the interval 6.2 to 7.4. Box plots, Figure *, illustrate that two wells, MW-28 and MW-30A, have pH measurements entirely within the acidic range values whereas the remaining four wells include both acidic and basic measurements. Time trend plots, Figures * through *, depict moderate fluctuations in wells MW-27A, MW-29, and MW-55. In contrast, pH in wells MW-30A and MW-42D appears to be relatively more stable. No temporal trends are evident. MW-28, MW-29, and MW-30A each have several values below the secondary federal drinking water standard minimum of 6.5.

Specific Conductance

Measured in the field, specific conductance in the Stratified Drift unit typically ranges from about 100 µS/cm to 300 µS/cm, with the exception of MW-30A and MW-42D which have ranges of 550-700 µS/cm and 1400-1800 µS/cm, respectively. As indicated by box plots in Figure *, all individual wells except MW-42D have fairly narrow ranges with only one low-lying outlier appearing in MW-29. Despite the broader span of values in MW-42D, all points fall within 1.5 times the interquartile range. The time trend plots, Figures * through *, confirm the stability of specific conductance within each well. With the exception of MW-42D, only slight fluctuations occur and no trends of increase or decrease in conductivity are evident during the sampling period. In MW-42D, there is apparently a slight declining trend occurring over time. This decline continues from the previous reporting period during which values decreased from about 2300 µS/cm in 11/86 to about 1800 µS/cm in 7/89.

COD

Although the range of COD is quite broad (up to 12,000 mg/L) in this aquifer, it is evident from the box plots in Figure * that the high-end values are caused by outliers in wells MW-27A and MW-28. The time plots (Figure * through *) clearly indicate the majority of values to be below the detection limit of 10 mg/L in each well, except in the case of MW-42D which has values ranging from the limit of detection to almost 50 mg/L. MW-42D also shows large fluctuations of up to 30 mg/L between consecutive readings. Likewise, MW-30A shows some fluctuation within those few readings that are above the limit of detection. Data from the previous reporting period (10/86 - 7/89) also display high variability for MW-42D with fluctuations of up to 80 mg/L between points.

Chloride

Chloride concentrations are generally below 7 mg/L in this aquifer, except in wells MW-30A and MW-42D which range up to about 38 mg/L and 78 mg/L, respectively. For the most part, ranges are narrow in wells 27A, 28, 29, and 55, and values lie fairly close to the limit of detection with little variability (refer to time plots, Figure * through *). In contrast, MW-30A shows higher variability as does MW-42D, and both of these wells have one or more outliers. In MW-30A, there appears to be an increasing trend from 10/90 until the concentration peaks in 11/91 at about 39 mg/L (averaged on time plot). For MW-42D, there is a mild declining trend throughout the period which continues a declining trend observed in the previous reporting period. MW-42D also shows a seemingly anomalous value midway through the sampling period, which marks a decrease of about 75 mg/L. All values in the Stratified Drift unit are below the secondary federal drinking water standard of 250 mg/L.

Fluoride

Fluoride concentrations are typically below 0.4 mg/L except for two outliers in MW-42D which have values of 1.2 and 1.7 mg/L. As indicated by the box plots in Figure *, the ranges within each well are relatively narrow. Although partially obscured because many points are at or below the limit of detection, the time plots indicate minor fluctuations in MW-27A, MW-28, MW-29, and MW-55, with perhaps moderate fluctuations in MW-30A, and significant fluctuations in MW-42D. No temporal trends are evident in any of the wells, however. All values are below the secondary federal drinking water standard for fluoride of 2.0 mg/L.

Total Inorganic Nitrogen

Total inorganic nitrogen, measured as the sum of nitrogen from nitrite, nitrate, and ammonia species, ranges up to 3.2 mg/L in MW-29, but is below 1 mg/L in the other wells. The outliers displayed in the box plots in Figure * have different sources. For instance, the low outlier in MW-27A is due to the ammonia concentration, as is the high outlier in MW-55. The high outliers in MW-28 and MW-30A are due to nitrate. The origin of one outlier in MW-42D is ammonia, for a second outlier, nitrate. As exhibited in the time plots, Figure * through *, the concentrations of inorganic nitrogen fluctuate over 1 mg/L in magnitude between consecutive readings in MW-29, but are only mildly variable in the remaining wells. No obvious trends are visible in the plots of concentration over time. All total inorganic nitrogen values are below the primary federal drinking water standard of 10 mg/L for nitrate-nitrogen alone.

Sulfate

Sulfate concentrations range from the limit of detection to about 50 mg/L, with one high outlier of 350 mg/L in well MW-28. The box plots, Figure *, indicate narrow concentration ranges for the most part, with a broader range of values in MW-28. Wells MW-27A, MW-29, MW-42D, and MW-55, have similar levels which fluctuate from below detection to about 15 mg/L, as depicted in the time plots, Figure * through *. MW-30A appears to be slightly different with levels between 10 mg/L and 30 mg/L. A substantial difference in seen in MW-28 with values ranging from about 12 mg/L to 50 mg/L in addition to the high outlier already indicated. It should be noted that there are fewer samples from this well which may explain, in part, the higher variability between readings. Except for the outlier in MW-28, all sulfate values are below the secondary federal standard of 250 mg/L.

Metal Parameters

Dissolved Arsenic

In the Stratified Drift unit, dissolved arsenic levels reside close to or below the limit of detection in all wells with the exception of MW-27A which has values of around 0.02 mg/L, and MW-42D which has values ranging from 0.02 mg/L to 0.12 mg/L. The box plots, Figure *, display narrow ranges in all wells except MW-42D. The broad range in MW-42D is due to large fluctuations of up to 0.1 mg/L between measurements which are illustrated by the time plots in Figures * through *. Previous data reported for this well show similar behavior. In the other wells, little variability is apparent particularly since many values are at the limit of detection. Overall, there are no temporal trends evident. The primary federal drinking water standard for total arsenic is 0.05 mg/L. All dissolved values are below this level except for seven of the ten readings from MW-42D. However, in all wells there are values which exceed the state standard of 0.05 μg/L for total arsenic.

Dissolved Barium

Of the six wells in this unit (see Figure * through *), MW-27A, MW-28, and MW-55 all have undetectable levels of dissolved barium. MW-29 has only one detection at 0.06 mg/L. In contrast, MW-30A has variable levels of dissolved barium ranging from below detection to 0.11 mg/L, and MW-42D has variable readings ranging from below detection to 0.2 mg/L. No values exceed the state and federal primary standards for total barium of 1.0 mg/L, and no trends appear to be present.

Dissolved Copper

There are only four detections of dissolved copper in this unit, as displayed by Figure * through *: 0.005 mg/l in MW-29; 0.004 and 0.006 mg/L in

MW-30A (averaged on time plot); and 0.003 mg/L in MW-55. None of these values approaches the state and federal secondary standards of 1.0 mg/L for total copper.

Dissolved Iron

Concentrations of dissolved iron are highly variable in this unit, as illustrated by the time plots, Figures * through *. There are several outliers in these wells evident in the box plots (Figure *). The highest values are found in MW-42D (3.8 - 10 mg/L), and all readings in this well exceed the state and federal secondary standard for total iron of 0.3 mg/L. Intermediate values are found in MW-28 (ND - 3.5 mg/L), with five out of six exceedances of the secondary standard, and in MW-30A (ND - 6.9 mg/L), with 23 out of 30 exceedances of the secondary standard. Lower levels are present in MW-27A (ND - 0.1 mg/L), MW-29 (ND - 1.8 mg/L--two out of 11 exceedances), and MW-55 (ND - 0.39 mg/L--one out of 12 exceedances). No trends are apparent.

Dissolved Manganese

Dissolved manganese levels in this unit range from below detection to 6.4 mg/L. The highest concentrations are present in MW-28 (ND - 6.4 mg/L--five out of six exceedances of the state and federal secondary standard of 0.05 mg/L for total manganese), and in MW-42D (2.6 - 4.6 mg/L--nine out of nine exceedances of secondary standards). Intermediate values are found in MW-30A which range from 0.11 to 3.2 mg/L, including several outliers. All 30 readings from this well lie above the secondary standard. Levels are lower in MW-27A (0.04 - 0.08 mg/L--12 out of 13 exceedances), MW-29 (ND - 0.11--one value above the secondary standards), and MW-55 (0.094 - 0.13 mg/L--12 out of 12 exceedances). Variability appears to be high for dissolved manganese as displayed by the time plots, Figures * through *, especially for MW-28 and MW-30A. No trends are seen.

Dissolved Zinc

As illustrated by the time plots, Figure * through *, MW-30A shows the most variability in levels of dissolved zinc, with values ranging from below detection to 0.27 mg/L. The other wells show fewer detections with maximum concentrations, as follows: MW-27A (0.073 mg/L), MW-28 (0.03 mg/L), MW-29 (0.05 mg/L), MW-42D (0.04 mg/L), and MW-55 (0.03 mg/L). None of these values exceeds the 5.0 mg/L state and federal secondary standards for total zinc, and there are no apparent temporal trends in the data.

<u>Organic Parameters</u>

Acetone

Acetone is detectable in samples from all of wells except MW-28 (refer to time plots, Figure * to *). However, no well has more than four detections. The maximum values are as follows: MW-27A (36 µg/L), MW-29 (14 µg/L), MW-30A (42 µg/L), MW-42D (19 µg/L), and MW-55 (20 µg/L--averaged on time plot). No trends are evident. There are no applicable state or federal standards for acetone.

2-Butanone

There are only two detections of this compound: MW-29 (15 µg/L) and MW-42D (9 µg/L) in the Stratified Drift unit. There are no state or federal standards for 2-butanone.

Methylene Chloride

Methylene chloride is detectable in samples from all wells. The maximum values are as follows, with the number of exceedances also listed for values above the state standard of 5 μg/L: MW-27A (10 μg/L, 1/13), MW-28 (7.5 μg/L, 1/6), MW-29 (4.5 μg/L), MW-30A (52 μg/L, 34/34), MW-42D (8 μg/L, 1/9), and MW-55 (19 μg/L, 2/12).

Toluene

Toluene is only detectable in MW-42D; there are two readings both at 2.0 μg/L. No state or federal standards are applicable for toluene *

1,2-DCA, 1,2-DCE, Benzene, TCE, and Vinyl Chloride

MW-30A is the only well with detectable levels of 1,2-DCA, 1,2-DCE, benzene, TCE, and vinyl chloride. The levels of 1,2-DCA are variable and range up to 5.0 μg/L with 27 out of 34 values exceeding the state standard of 0.5 μg/L, but none exceeding the federal standard of 5 μg/L. 1,2-DCA appears to peak in 12/90 and subsequently decline. 1,2-DCE ranges from below detection to 170 μg/L, and appears to be increasing (see time plot, Figure *). There are no applicable standards for 1,2-DCE. Benzene levels rise to 3.9 μg/L in 12/90, then decline steadily to below detection. 18 of 34 sample values exceed the state standard of 1.0 μg/L for benzene. There is one high spike of TCE detected in 12/90 (23 μg/L) with the rest of the detections close to 3.0 μg/L. Three of 34 readings from this well exceed the state standard of 3 μg/L for TCE. Vinyl chloride appears to peak in 6/90 at 26 μg/L then decline steadily to 5 μg/L. Of 34 readings, 29 exceed the state standard of 0.02 μg/L for vinyl chloride (note that the standard is below the limit of detection for this compound).